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INTERNAL FACTORS INFLUENCING EGG PRODUCTION IN THE RHODE ISLAND RED BREED OF DOMESTIC FOWL

A SURVEY OF THE PROBLEM OF EGG PRODUCTION AND A PRELIMINARY ANALYSIS OF AN EGG RECORD INTO ITS CONSTITUENT ELEMENTS

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INTRODUCTION

A SURVEY of the problem of egg production, such as is made in the present paper, seems desirable at the present time because of the great interest taken in breeding for increased egg production. While the various factors discussed are familiar, to a degree at least, to most poultry keepers, nevertheless they are ignored in breeding practise and reliance placed upon the numerical record alone as a sufficiently detailed and accurate description of a hen's performance, although, as will be pointed out in a later section, identical numerical records result from quite diverse combinations of factors.

The point of view which we have been led to adopt may be stated in one form as follows: The *egg record* of a hen, expressed as a given number of eggs per unit of time and taken by itself, is not a sufficient measure or description of egg production, even under a favorable environment, for the record is the result of the interaction of a number of innate factors. Some of these factors, such as rate of growth, are quite distinct from egg production, while

others, such as rhythm, are almost inseparable from egg production itself. The numerical record of a hen shows only the number of eggs laid, but does not show the component elements which enter into the making of such a record. All these various elements must be studied individually and the influence exerted by each on egg production worked out. Moreover, the mode of inheritance of the separate factors must also be determined.

Further, it should be noted that the interrelation of the various factors is so complex that it is difficult to describe each by itself. In nearly all cases the bearing of some other factors must be considered to a certain extent, at least, along with that factor which is specifically under discussion.

It is important to observe that while the results obtained for the Rhode Island Reds described in this paper differ in several respects from those obtained by Pearl ('12) for Barred Plymouth Rocks, these differences are inherent in the birds themselves and are on a par with the visible differences, such as color, that exist between the two breeds. Pearl has anticipated that differences in fecundity in various strains and breeds are likely to be found. He states as follows:

> The writer has no desire to generalize more widely from the facts set forth in this paper than the actual material experimentally studied warrants. It must be recognized as possible, if not indeed probable, that other races or breeds of poultry than those used in the present experiments may show a somewhat different scheme of inheritance of fecundity. . . . I wish only to emphasize that nothing is further from my desire or intention than to assert before such investigations have been made that the results of the present study apply unmodified to all races of domestic poultry.

It is clear, then, that a complete knowledge of fecundity and its inheritance in domestic birds can only be obtained by a careful study of egg production in all breeds and perhaps even in several strains of the same breed. As shown later on, one of the several factors that determine winter egg production is characteristic of Pearl's

Barred Plymouth Rocks, while another is characteristic of my Rhode Island Reds.

The data in this paper are obtained from a flock of 220 March and April hatched pullets placed in the laying houses in the fall of 1913, together with the data on winter egg production from the flock (numbering 482 pullets) placed in the laying houses in the fall of 1915, although the composition of this flock was not the same as that of 1913–14, because it had been altered by the addition of several other strains in order to overcome the unsatisfactory vitality of the original flock. The addition of new blood apparently increased the variability in some respects as shown by the statistical constants (*cf.* Figs. 1 and 2, also 10 and 10*a*). The winter production of the flock of 1914–15 was decidedly poor and apparently not normal, probably due largely to environmental conditions, and hence data from this flock have not been used.

It is impossible within the limits of this paper to present detailed data on all points discussed. To the reader who is unfamiliar with egg records, it may be said that an inspection of the records reveals the essential nature of the problems.

The original flock came mainly from one of the leading showroom strains of the country, to which were added a few individuals from another showroom strain. Neither strain, so far as known, had been especially bred for egg production, nor had any of the strains added in 1915.

Ways of Measuring Egg Production

It has been customary in times past to determine a hen's egg production by her record expressed in the number of eggs per year, the year usually running from November 1 through the succeeding October 31. At other times the first-year record of the hen has been taken as the time unit, beginning with her first egg and running 365 days therefrom. More recently, the Maine Experiment Station has used the period beginning with the first egg of a pullet and extending to March 1 as the unit of

measurement, since March 1 serves as a convenient calendar date, near the end of the winter cycle. Still more recently the same workers have suggested that even a shorter period would be desirable, because it is held that a hen only reaches her highest possibilities under favorable conditions. Recently the Utah Station (Ball, Turpin and Alder, '14) has suggested that for Leghorns the records be kept for three years, since hens that lay poorly the first year often lay much better during the second or third. Rice, however, ('13) has published data on this point, which show that such birds are the exception rather than the rule.

A year, however, may be considered to be a natural unit. During this period the whole cycle of seasonal changes is gone through with. Moreover, this period bears a definite relation to the bird's life cycle, for its beginning may be taken to correspond to the beginning of egg production in the fall, while its close roughly corresponds to the cessation of egg production the next fall, usually coinciding with the onset of the fall moult, though, of course, in some individuals, the biological year exceeds 365 days. Thus, the year would seem to mark a pretty definite period in the life of the bird as to her innate capacity for egg production. In this paper we have used both winter and annual periods as measures of production, as the necessities of the moment required.

There are some objections to each of the two common methods of determining the point at which the year begins. If the year begins with the first egg of each individual, the differences in age at which the first egg is produced are neglected. If a given point in the year is chosen and the production of all individuals within a year from this date recorded, differences in time of hatching are neglected. Possibly a more satisfactory method would be to take 365 days from the beginning of egg production in each flock of equal age, or else from the average date at which production begins.

The terms "high producer" and "low producer" are

frequently encountered, but each is used very loosely. The use, either of the term "higher producer" or "low producer" without qualifications of any sort can scarcely be considered sufficiently precise. Unless qualified by the word annual, the term "high producer" in this paper will be understood to refer to the winter record only. Pearl ('12) has defined a high producer as a bird that lays over 30 eggs during the winter, a mediocre producer as one that lays during the winter but that lays fewer than thirty eggs, while a zero producer does not lay at all during the winter. As will appear later, the use of the numerical value of the record as its sole characteristic is insufficiently precise. The term "true mediocre producer" will be used to denote a mediocre producer in the sense (Pearl's) explained below, while the term "mediocre (under 30 eggs) producer" will be used elsewhere.

The Influence of External Factors.—A brief consideration of the relation of external factors to egg production is necessary before considering internal factors.

External factors may be divided into two classes: first those that operate rather directly upon egg production, and secondly those that operate indirectly, through their influence on the organism as a whole.

Under the head of direct factors should be mentioned housing, climate, food, general care, etc. It should go without saying that the birds must be properly fed and kept under conditions generally recognized as suitable for maximum egg production. It is not yet clear, however, that the optimum conditions are fully known, or that they can be obtained at will, for with the present appliances for keeping poultry, only the crudest sort of approximation can be made toward securing a uniform environment. For example, one is never certain with open-front houses that a draft may not strike one portion of the flock, while on the roosts, but not another. There are many little things of this sort which can not at present be controlled, nor is it definitely known in what way these "little things" influence egg production. Some

appear to be without any influence whatsoever; others appear to be of varying degrees of importance.

Thus, it is not easily possible to overemphasize the importance of the environment in relation to egg production. At best, certain elements of the environment are partially controlled and *similar* conditions supplied to the members of the flock under experimentation, but it is impossible with the best practical facilities at present available to furnish *identical* conditions to all individuals of the same flock. At the very best one can only go through the motions of providing such conditions. Moreover, one may be forced to modify the procedure selected in order to keep the birds in good condition. Furthermore, *individuals* or *strains* may not react in the *same fashion* to *identical conditions*.

The difference in the reaction of individuals of the same strain to similar conditions, particularly when these conditions fall near the critical point for the strain (or species), is a matter of considerable importance, especially when a character such as egg production is under study, and more especially when it is impossible to control certain important elements of the environment. As long as the environment is not too far from the optimum, birds of low vitality, for example, may do quite as well as birds of much higher vitality, but when the environment approaches either end of its range, then its effects begin to manifest themselves.

A full discussion of the possible influence of the environment, either directly or indirectly, upon egg production as a whole or upon any of the several factors influencing production is outside the scope of this paper. While the reader should bear in mind the possibility that the environment has introduced disturbing factors, every effort has been made to keep all controlable elements, such as feeding and housing uniform.

Turning now to internal factors, we find that these also may be considered under two heads. We have little to do with the factors falling under one of these heads, for

their effect is exerted only indirectly. They undoubtedly play an important part in egg production, but like many external factors they are without influence unless they fail in some way. Such factors are the capacity to digest and assimilate food, to excrete waste matters properly, etc. It is not my purpose at this time to discuss such factors. Those internal factors with which we are mostly concerned are those whose relations to egg production are much more obvious. They are rate of growth of the chick, cessation of growth, the attainment of both bodily and sexual maturity, moults, the size of the bird, the stamina of the bird, the presence or absence of cycles, litters or clutches of production, the rhythm of production, the rate of production for definite time intervals, age at first egg, and broodiness. Some of them are clearly separable from egg production. Others are so closely interwoven that it is impossible to say that they are not phases of egg production. Whether or not this is so, is of no immediate importance from the standpoint of inheritance, since the result will probably be the same whether they are treated as genetic factors that are separable from egg production or treated as groups into which egg production itself may be divided. These factors may be regarded as phases of egg production if one desires, but on the whole it has seemed profitable to regard them as factors influencing egg production.

Rate of Growth, Bodily Maturity, Cessation of Growth, Sexual Maturity[1]

These interrelated factors are closely interwoven in their effect on egg production. Under normal conditions it is clear that sexual maturity is indicated by the beginning of egg laying, and may be measured by a bird's age at her first egg, *i. e.*, the length of time elapsing between the date hatched and date of first egg. Sexual maturity, however, demands certain antecedent conditions before it can become manifest. Among other conditions is a cer-

[1] Unless otherwise stated, reference here is to the female only.

tain body size, which depends upon the rate at which the individual grows, as well as the limiting size for that individual. That is, size at a given age is the result of rate multiplied by time, up to certain limiting values determined by the genetic composition. Cessation of growth, however, does not necessarily coincide with the onset of sexual maturity nor even with general bodily maturity. Although it is certain that the hen is heavier in her second autumn than at the beginning of egg production, our data show that there is little or no growth during the first winter. We must, then, distinguish between sexual maturity, which is capable of manifesting itself as soon as the body reaches a certain size, from that maturity which is not attained until long after the adult size is reached. At present the relation between sexual maturity and bodily maturity has not been worked out. Some extreme phases, however, of the interrelation appear a priori probable. Chicks that grow very rapidly naturally tend to reach sexual maturity at a very early period in their life. They may or may not start in laying immediately after reaching full size. Other birds grow very slowly and can not lay before a certain size is reached. Therefore, they must of necessity reach sexual maturity relatively late in life. It may be impossible for birds of this sort to reach sexual maturity before spring if hatched during the usual breeding season (April, May). The general effect of slow growth, then, will be to lower the record made by such individuals, although they may be otherwise identical with those that grow more rapidly.

Combined with the factors mentioned are the factors that limit the size finally reached. As pointed out above, size results from rate of growth times length of period through which growth continues. Each factor is determined in part by the environment and in part by the genetic constitution of the bird.

The following combinations of factors (Table I) and their effect on egg production may be *assumed*. Each factor is treated as though it were wholly independent

of the others. Early sexual maturity is assumed to be a constitutional tendency to begin laying as soon as a sufficient body size or body maturity is reached, while late sexual maturity is assumed to be a tendency to delay production until after body maturity is attained. This heading, however, does not refer to the objective attainment of sexual maturity which is shown by the column on "time of first egg." The length of the growth period also is assumed to be determined by the attainment of bodily maturity.

TABLE I

VARIOUS COMBINATIONS OF HYPOTHETICAL GROWTH FACTORS WITH THEIR EFFECT ON WINTER EGG PRODUCTION

Rate of Growth	Sexual Maturity	Growth Period	Probable Time of First Egg	Probable Winter Egg Production
Rapid	Early	Short	Early	High
"	Late	Short	Late	Low
"	Early	Long	Relatively late	Medium
"	Late	Long	Late	Low
Slow	Early	Short	Relatively late	Medium
"	Late	Short	Relatively late	Low
"	Early	Long	Late	Low
"	Late	Long	Very late	Zero

It appears from this table that early sexual maturity can become fully effective only when combined with rapid growth during a short growth period.

The effect of the activities of some of these factors as bearing on winter egg production may be given more specifically as follows: If we measure egg production by the number of eggs laid before the 1st of March, assuming for the moment that this point represents, approximately at least, a definite point in the history of the egg production of each individual, it follows that the birds hatched during April and May, or to take a definite point for the purposes of illustration—April 15—which mature at five months, as is sometimes the case, will begin to lay September 15 and will lay a large number of eggs before March 1, provided, of course, that they do not moult. On the other hand, true mediocre productivity (slow rate) associated with early maturity will tend to force a bird

out of the class of mediocre producers, when measured by a specific number of eggs, into that of the high class. If, then, one is dealing with a flock in which these degrees of maturity exist, it is evident that extreme care must be taken to avoid confusion due to differences in maturity or rate of growth.

Differences in maturity may be observed among the males as well as the females, although there is no precise objective point at which a male may be said to have become mature, which is comparable to the first egg of a pullet. On the whole, the larger birds tend to mature later than the smaller, though the rule is by no means rigid, since some small birds grow slowly while some large birds grow quickly. Since age at first egg is so large a factor in determining the kind of record a bird makes, one has a physiological character in the male of considerable value as an index of his capacity for producing females that will mature at a given age.

The age of a bird when she produces her first egg does not coincide necessarily with bodily maturity, theoretically at least, although it seems that a certain size must be reached before the bird can begin to lay. On the other hand, the relation between body size and age at first egg as frequently encountered is of a sort such that the larger birds tend to lay at a later absolute age than the smaller ones hatched the same day. There are many exceptions, however, to this rule. It would, perhaps, be better expressed to say that more heavy birds lay late in life than early, while more of the lighter birds lay early than late. For one of the flocks, the coefficient of correlation between age at first egg and weight has been calculated and found to have a value of $+.5473 \pm .0216$.

The influence of the date at which the first egg is produced as well as the relation of age at first egg to the number of eggs laid during the winter months is shown in the series of records shown in Figs. 3 and 4 (Page 78). These records have been selected in such a way that the rate of production is nearly constant, although the date of hatch-

ing of the individual birds covers a period of five weeks. The records are to be read as follows: The number in the upper left-hand corner is the hen's number. The *vertical* mark in *each* square indicates that an egg was produced on that day. The totals are given for each month while the figure at the extreme right of the row headed

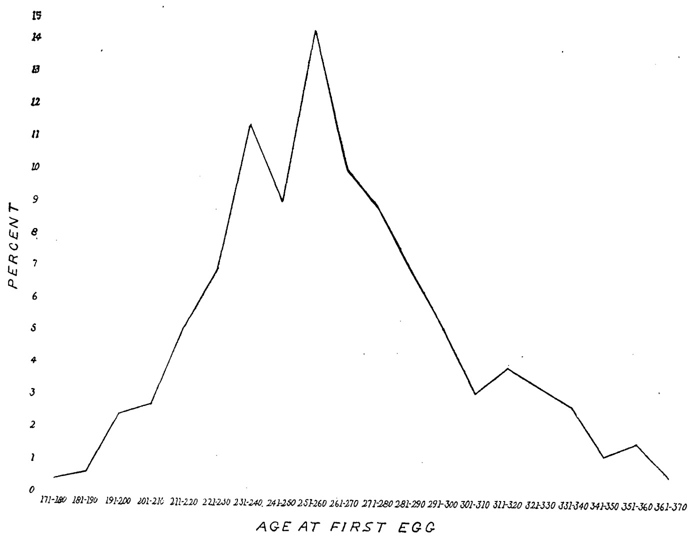

FIG. 1.[8] Graph showing the percentage of the flock beginning to lay at the age (in days) indicated by the class limits. Flock hatched in March, April and May, 1915. M = 263.19, S. D. = 37.71; $C. V._2 = 43.00$, $C. V._1 = 14.33$.

"February" is the total number of eggs for the winter period. The records for March and April have also been included in order to show the type of record made by birds that begin to lay very late in the season. These records show clearly that no sharp dividing line exists in the number of eggs laid. On the contrary, it is clear that birds hatched at the same time begin to lay at widely different dates and that in consequence differences in egg yield for the winter period result. That this result is of general applicability to our flocks is shown by the fair

[8] In calculating the $C. V._{(2)}$ for the data given in Figs 1 and 2, the mean was taken as the difference between the mean age and the lower end of the range of Fig. 1.

amount of homogeneity in the flocks in respect to rate of production as described below.

Graphs showing the age at first egg for the flocks of 1913–14 and 1915–16 are shown in Figs. 1 and 2. The former (Fig. 2) is unimodal and has a narrow base, the shape of the curve indicating a high degree of homo-

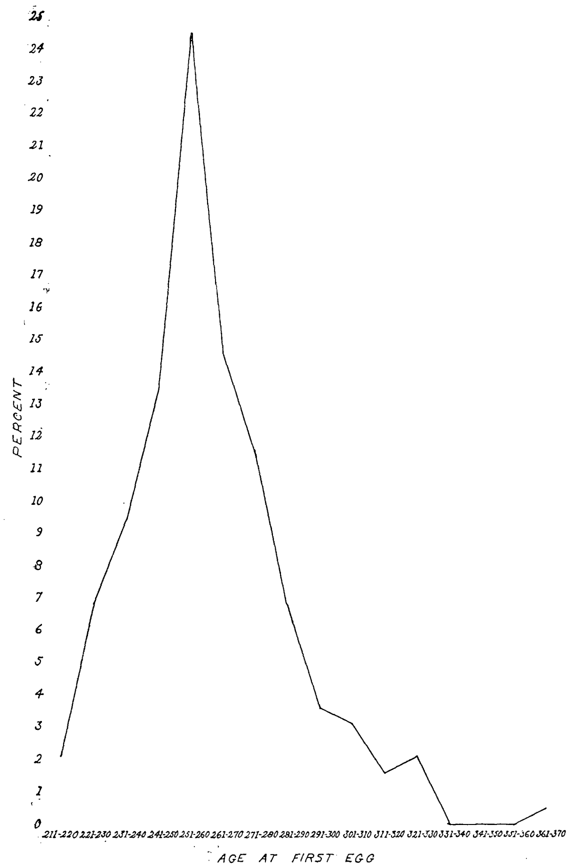

FIG. 2.[8] Graph showing the percentage of the flock beginning to lay at the age (in days) indicated by the class limits. Flock hatched in March and April, 1913. M = 261.18, S. D. = 24.34, C. V.$_2$ = 28.41, C. V.$_1$ = 9.32.

geneity in the flock. As might be expected from the nature of the data (which is affected by the environment in only one direction, *i. e.*, toward a retardation of the age at first egg) the lower part of the right-hand side slopes

off more gradually than the left. The mean has a value of 261.18 days.[2]

The curve for the flock of 1915–16 (Fig. 1) is somewhat unlike the preceding. It is distinctly bimodal, but it is not altogether clear that this bimodality indicates two genotypes, for it may be due to chance alone. The base is broader than for the 1913–14 curve, indicating less homogeneity of the flock in this respect, although the same gradual slope on the right-hand side is apparent. There are reasons, however, for believing that the left-hand side of the graph for the flock of 1913–14 was shortened by the methods of handling the pullets that fall. The mean has a value of 263.18 days. The difference between this graph and the first is undoubtedly due to the changes in the composition of the flock as described in an earlier paragraph.

Graphic representations of the day on which the various members of the flock produced their first egg are shown in Figs. 5 and 6. The data for the two flocks, *i. e.*, 1913–14 and 1915–16, are divided into groups according to the month in which the pullets were hatched. Each dot in the figure represents the first egg of a pullet and is placed in a square corresponding to the date on which the egg was laid. If more than one pullet began to lay on a given date, there is a dot for each pullet.

There are some interesting differences and resemblances between the groups mentioned in the distribution of the first egg through the various months. In all instances the pullets laying for the first time come in slowly during the first few weeks. Then follows a period of six to eight weeks during which the new pullets come in at a faster and fairly uniform rate. This period is followed by a third period when new pullets come in slowly, the last of the period representing the stragglers. The fairly uniform scatter is due in part to the inclusion of several

[2] In this paper we have given only those statistical constants that appear to be particularly pertinent and as a rule have omitted the probable error, especially where "*n*" is large, unless there has been special reason for inserting it.

No. 4846 HATCHED MARCH 21, 1915. AGE AT FIRST EGG, 191 DAYS

Date 1915–16	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Totals	
Sept.																												/	/		■	2	
Oct.	/	/		/		/		/	/	/		/	/	/	/		/	/	/	/		/	/		/	/		/	/	/		22	
Nov.	/		N	/		/	/	/		/	/		/	/		/	/		/	/		/	/	/	/		N	/	/	/	■	20	
Dec.		N	/		/		/	/		/	/	/	/		/	/	/		/	/		/	/	/		/	/	/		/	/	21	
Jan.	/	/		/	/	/	/		/	/	/		/	/	/		/	/	/		/	/		/		/	/		/	/		22	
Feb.	/	/		/	/		/	/		/	/		/	/		/	/	/		/	/	/		/	/		/	/		■	■	20	107
Mar.	/		/		/		/	/		/	/		/	/		/		/		/	/		/	/		/		/		/		18	
Apr.	/	/		/	/	/	/		/	/	/	/		/	/	/	/		N						N			N N	N	N	■	14	

No. 4921 HATCHED MARCH 21, 1915. AGE AT FIRST EGG, 219 DAYS

Date 1915–16	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Totals	
Sept.																															■	0	
Oct.																										/		/		/		3	
Nov.	/		/		/		/	/		/		/		/		/		/	/		/		/	/		/	/			/	■	17	
Dec.	/	/		/	/		/	/	/	/			/	/	/	/	/		/		/	/	/	/		/	/	/	/	/	/	24	
Jan.		/	/	/	/		/	/	/		/	/		/	/		/	/		/	/		/	/	/		/	/	/		/	22	
Feb.		/	/		/		/		/		/	/		/		/	/		/	/	/		/	/		/	/		/	■	■	18	84
Mar.	/	/		/	/	/	/	/	/		/	/	/	/		/	/	/	/	/	/		/	/	/	/	/	/	/	/	/	27	
Apr.	/		/	/	/	/	/	/	/	/	/	/		/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	■	28	

FIGS. 3 AND 4. Daily records of Rhode Island Red pullets hatched in 1915, arranged in order of decreasing total winter eggs to show the effect of approximately equal rates of production, but of different dates of first egg on the total winter production, as shown by the numeral at the right of the February record. March and April records are included to show that no fixed date can be selected as a dividing line. 1 = an egg; N = on nest but did not lay; B. L. = removed to broody coop; A = returned to pen.

No. 4514 HATCHED MARCH 7, 1915. AGE AT FIRST EGG, 266 DAYS

Date 1915–16	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Totals	
Nov.......																								N			N	/		/	■	2	
Dec.......	/		/	/	/		/		/	/		/	/		/		/	/		/	/		/	/		/	/		/	/		20	
Jan.......	/	/		/	/		/	/		/	/		/	/		/	/		/	/		/	/		/	/		/	/		/	21	
Feb.......	/		/	/		/	/		/	/		/	/		/	/		/	/	/		/	/	/		/	/	/		■	■	20	63
Mar.......	/	/		/	/	/		/	/	/	N.	/	/	/	/		/	/	/		/	/	/		/	/		/	/	/		23	
Apr.......	/	/	/		/	/	/	B L					A N				/		/	/	/		/	/	/		/	/	/	/	■	17	

No. 5297 HATCHED APRIL 11, 1915. AGE AT FIRST EGG, 268 DAYS

Date 1915–16	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Totals	
Nov.......																															■	0	
Dec.......																																0	
Jan.......				/	/	/		/	/	/	/		/	/	/		/	/	/		/	/		/	/		/	/	/		/	21	
Feb.......	/		/	/			/	/		/	/		/	/		/	/	/		/	/		/	/	/		/	/	/	■	■	20	41
Mar.......		/	/		/	/	/		/	/	/		/	N	/	/		/	/	/		/	/		/	/	/	BL /				20	
Apr.......	A		N	/		/	/		/	/	/	/	/	/		/	/	/	/	BL /			A BL				A				■	14	

FIGS. 3 AND 4.—*Continued.*

No. 4620 HATCHED MARCH 14, 1915. AGE AT FIRST EGG, 312 DAYS

Date 1915–16	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Totals	
Nov.......																															■	0	
Dec.......																																0	
Jan.......										/						/	/	/		/	/	N		/	/	/		/	/	/		12	
Feb.......	/	/	/		/	/	/		/	/		/	/	/		/	/	/	/		/	/	/	/		/	/	/	/	■	■	23	35
Mar.......		/	/	/	/	/		/	/	/	/	/	/		/	/	/	/	/		/	/	/	/	/		/	/	/	/	/	26	
Apr.......	/		/	/	/	/	/	/	/	/		/	/	/		/	/	/		/	/	/	/		/	/	/	/	/		■	24	

No. 5180 HATCHED APRIL 4, 1915. AGE AT FIRST EGG, 294 DAYS

Date 1915–16	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Totals	
Nov.......																															■	0	
Dec.......																																0	
Jan.......																							/		/	/	/	/		/	/	7	
Feb.......	/		/	/		/	/		/	/		/	/	/	/	/		/	/	/		/	/	/	/		/	/	/	■	■	22	29
Mar.......	/	/		/	/	/	N	/		/	/	/	/	/	/	/		/	/		/	/		/	/		/	BL				21	
Apr.......	A	N	N				/	/		/	/	/	/	/	/	/	/	/		/	/	/	/	/	/	/	/		/	N	■	20	

FIGS. 3 AND 4.—*Continued.*

No. 5149 HATCHED APRIL 4, 1915. AGE AT FIRST EGG, 304 DAYS

Date 1915–16	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Totals	
Nov......																																0	
Dec......																																0	
Jan.......																																0	
Feb......		/		/		/	/		/	/		/	/	/		/	/	/		/	/	/	/	/		/	/	/	/			21	21
Mar......	/		/	/	/	/	/	/		/	/	/	/	/	/	/	/	/	/	/		/	/	/	/	/	/	/	/	/	/	28	
Apr......	/	/		/	/	/	N		/	/		/	/	/	/	/	/	/		/	/	/	/	/		/	/	/	/	/		24	

No. 4568 HATCHED MARCH 14, 1915. AGE AT FIRST EGG, 336 DAYS

Date 1915–16	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Totals	
Nov......																																0	
Dec......																																0	
Jan.......																																0	
Feb......													/		/	/		/	/		/	/	/		/	/	/		/			12	12
Mar......	/	/	/	/		/	/	/	/	/	N	/	/	/	/	/	/		/	/	/	/		/	/	/	/		/	/	/	26	
Apr......	N /		/	/	/	/		/	/	/	/		/	/	/	/		/	/		/	N /		/	/	/		/	/	BL /		23	

FIGS. 3 AND 4.—*Continued.*

No. 5192 HATCHED APRIL 4, 1915. AGE AT FIRST EGG, 334 DAYS

Date 1915–16	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Totals	
Nov......																															■	0	
Dec......																																0	
Jan......																																0	
Feb......																														■	■	0	0
Mar......			/		/	/			/		/	/		/	/	/		/	/	/	/		/	/	/	/	/	/	/			20	
Apr......											/	/		/	/	/		/	/	/	/		/	/	/	/		/	/	/	■	16	

No. 5201 HATCHED APRIL 4, 1915. AGE AT FIRST EGG, 352 DAYS

Date 1915–16	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Totals	
Nov......																															■	0	
Dec......																																0	
Jan......																																0	
Feb......																														■	■	0	0
Mar......																					/		/	/	/		/	/	/		/	8	
Apr......	/		/	/	/		/	/	/		/	/	/	/		/	/	/		/	/		/	/		/	/	/	/		■	22	

FIGS. 3 AND 4.—*Concluded.*

HATCHED IN MARCH, 1915

Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Per Cent.
Sept........		·			·			·					··			·	·						·	·	·		·	··		··		8.3
Oct........		·	·	·			·	·	··		·		·		·	·		···			·	·		·	··	·		··	··	·		13.9
Nov........	·	···	:··	:··		··		·	···	·	··	··	·	···	··	·	:··	··	·	··		··		·	·	·	·	···		·		27.2
Dec........	···	·	·		·	···	:··	·	··		···	·	·	···	·		·	··	··	·		·	·	··	·	··	·	··		··	·	24.4
Jan........	·		··				:··	·		··	·	·					·		·								·	·	·	···	··	12.2
Feb........	··		·	··		·				·	·		·	·	·	·				·		·				·			·			8.9
Mar........			·				·		·					·				·	·									·				3.9
Apr........		·																						·								1.1

HATCHED IN APRIL, 1915

Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Per Cent.
Sept........																																
Oct........																							·			·						1.1
Nov........					·		·	·		·	·	·		·		··		··		··		··	·	·			··	···		:··		14.5
Dec........	·	·	···	·	··	···	··	··	·		··	:::	··	·		:··	···	·	···		··	·	··	··	···		···	··	···	::·	·	34.6
Jan........	··		··	···	···	::·			·	·	··	···	··	·		:··	·			··	··	·	·	··		·	··	·	·	···		25.7
Feb........	·	···	·	·				·		·	·	··			·			·	···		·		·	·	·	·	·		·			12.8
Mar........	·		:··					·	···	·			·		·	·					·	·					··		·			10.1
Apr........										·																	·					1.1

FIG. 5.

HATCHED IN MAY, 1915

Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Per Cent.
Sept.																																
Oct.																																
Nov.																																
Dec.				•			•			•				•				•				•	•	••		••		•		••	•••	12.5
Jan.	•			••• •		••		•	•••	•	•		••	••	••	•••		••• •	••	••	•••	••	•	•	•••	••	•	•	•••	•	•••	37.5
Feb.	••• •	••• ••	••• ••	••	•••	•		•	•	•	••		•	•••	••	•	••	••			••		•	•••		•		•				32.4
Mar.	•••		•••			••		•••	•				•		•	•		•		•	•	•		•				•				15.4
Apr.	•									•			•																			2.2

FIG. 5.—*Concluded.* Diagram to show the date on which the first egg of each member of the flock was laid. Flock of 1915–16.

hatches on one chart, and also to the ungrouped data, for if the data be grouped in 10-day periods, a curve is ob-

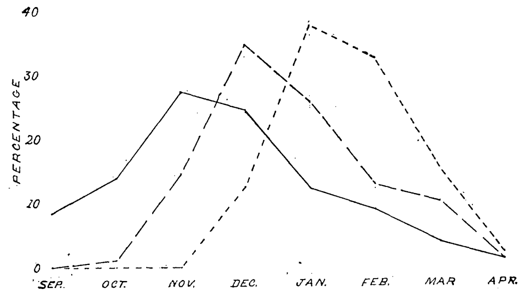

FIG. 5*a*. Graph showing the percentage of the flock of 1915–16 that began to lay in the month indicated. From Fig. 5. ——— March, — — — — April, and - - - - - May hatched pullets, respectively.

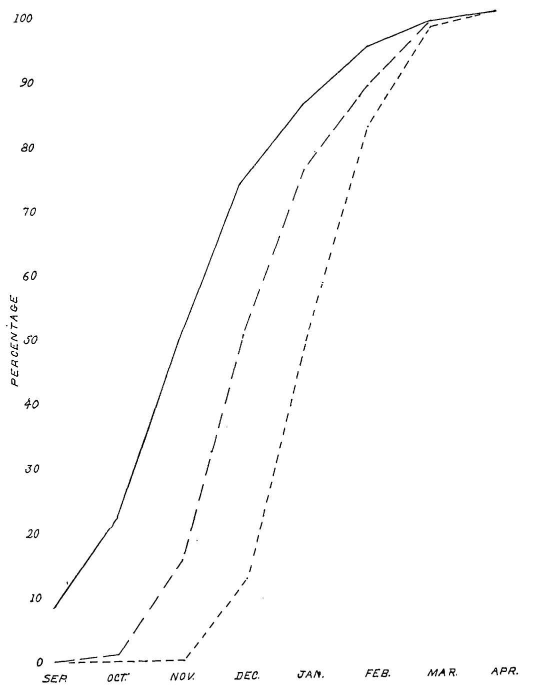

FIG. 5*b*. Graph showing the percentage of the flock of 1915–16 that began to lay during or before the month indicated. From Fig 5. ——— March, — — — — April, and - - - - May hatched pullets, respectively.

tained similar to the one that results from the combination of the age at first egg curves of several consecutive hatches.

HATCHED IN MARCH, 1913

Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Per Cent.
Sept........																																
Oct........																																
Nov........												•		•			••		•					••		•		•	••	•		18.5
Dec........		•	•	•	•••	•	••	•	•	•	•	•••		•••	••		•	•	••••		•	•		•		•		••	••	•	••	58.5
Jan........			•	•		•				•						•	•			•		•				•				•		15.4
Feb........	•								•						•		•															6.2
Mar........																•																1.5
Apr........																																

HATCHED IN APRIL, 1913

Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Per Cent.
Sept........																																
Oct........																																
Nov........													•	•	•				••	•		•	•	••	••••	•		••	•••	•		16.5
Dec........					••	•	•	•	••	•	•		•	•	••••	••	••	••	•	••	••	•	•••	•••	•	••	•••	••	•••••	••	•	38.6
Jan........	••••••	•••	•	•••••	••		••	•••	•••	••	•		•	••		••	•	••		•	•	••			•		•	••		•		35.4
Feb........	•	•		•			••	•	•			•								•				•		•						8.7
Mar........	•																															0.8
Apr........																																

FIG. 6.

HATCHED IN MAY, 1913

Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Per Cent.
Sept.																																
Oct.																																
Nov.																																
Dec.								•						•				•			•					•		•				25.0
Jan.		•	•	••	•		•			•				•			•				•						•				•	50.0
Feb.				•				•			•			•			••															25.0
Mar.																																
Apr.																																

FIG. 6.—*Concluded.* Diagram to show the date on which the first egg of each member of the flock was laid. Flock of 1913–14.

HATCHED MARCH 22, 1915

Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Per Cent.
Sept.																																
Oct.			•					•	••		•					•						•		•					•			25.0
Nov.			•	•											•		•															11.1
Dec.							••		•			•		•								•	•		•	••		•		••		36.1
Jan.	•		•				•••	•				•																				19.4
Feb.	•					•																										5.6
Mar.																																0.0
Apr.									•																							2.8

FIG. 7. Diagram to show the date on which the first egg of each member of the flock was laid. This figure is based on a new sample of the original strain that made their winter record in 1915–16. See text.

In any one hatching group a period of several months elapses between the date the first pullet begins to lay and the date the last member of the flock starts. This period is longest for the March-hatched birds, apparently because the warm spring weather brings all the stragglers to laying and because the March-hatched birds are the first to lay in the fall. For the May-hatched birds the period between first and last pullet is shorter because they begin to lay later in the fall than the March-hatched birds.

For the March-hatched pullets of 1915–16, the initial period is nearly twice as long as for the April or May pullets. The date of the first egg of the first pullet is approximately a month later for the May than for the April pullets. The data, however, for 1913–14 are not quite comparable with those for 1915–16. In the first place it was impossible in 1913, because of lack of room, to begin putting the pullets into the laying quarters until late in October, while some were not finally in place until about the middle of November. The birds therefore did not get settled down at once. The March- and April-hatched pullets both began to lay at approximately the same time and although most (77 per cent.) of the March birds had commenced laying by January, a considerable percentage (viz., 44.9 per cent.) of the April pullets did not begin to lay until after Jaunary 1, which is approximately the same percentage (viz., 49.7 per cent.) obtained for the April pullets of the 1915–16 flock. It should be noted, too, that 73.9 per cent. of the March pullets of this year began to lay before January 1, so that the effect of the delay in housing the 1913–14 flock shows itself principally in a retardation of the first eggs of the March pullets, forcing a larger percentage of first eggs into December than would be normal for that flock. There is a further difference in the two years. The percentage of the April hatched pullets laying after February 1 was about 2½ times as great for the 1915–16 flock as for the 1913–14 flock, the ratio being 24 per cent. for the former to 9.5 per cent. for the latter.

There is another way in which the close relation between age at first egg (also date of first egg) and the winter egg record can be shown, for it follows that the higher the age at first egg the lower the winter record

TABLE II

AVERAGE WINTER EGG PRODUCTION FOR EACH WINTER MONTH OF 1915–16, BY HATCHES

Date Hatched, 1915	Number Pullets in Hatch	Average Winter Production	August	September	October	November	December	January	February
February 7...	12	66.83	5.9	14.3	11.9	5.2	2.6	10.8	16.2
February 14...	8	56.63	5.3	9.9	8.8	6.6	5.5	9.4	11.3
February 21...	13	65.92	1.8	10.5	10.9	10.1	8.8	10.8	13.1
February 28...	18	41.44	0.0	2.0	3.7	6.3	8.8	9.4	11.3
March 7.....	24	44.88	0.0	1.5	5.2	7.2	10.6	10.6	9.9
March 14.....	33	34.15	0.0	0.0	0.8	5.1	7.7	8.3	12.2
March 21.....	48	40.67	0.0	0.3	2.7	7.2	11.6	9.9	8.9
March 28.....	17	40.00	0.0	0.0	0.0	4.4	11.8	12.5	11.3
April 4......	29	29.31	0.0	0.0	0.1	1.0	8.0	9.4	10.7
April 11......	63	31.30	0.0	0.0	0.0	1.9	6.8	10.9	11.8
April 18......	47	29.26	0.0	0.0	0.0	0.6	5.9	10.4	12.4
April 25......	34	27.35	0.0	0.0	0.0	0.4	3.3	10.6	13.1
May 2.......	30	20.27	0.0	0.0	0.0	0.0	1.3	6.9	12.0
May 9.......	30	20.37	0.0	0.0	0.0	0.0	1.8	7.0	11.6
May 16.......	19	18.95	0.0	0.0	0.0	0.0	0.1	4.3	14.6
May 23.......	37	17.78	0.0	0.0	0.0	0.0	0.2	4.6	12.9
May 30.......	20	11.35	0.0	0.0	0.0	0.0	0.3	3.1	8.0

should be. In calculating this coefficient of correlation it is necessary that the birds should all be hatched at the same time, so that for our flocks, which were hatched at intervals of one week, it would be necessary to form as many correlation tables as there were hatches. The probable results did not seem to warrant the labor involved, at

TABLE III

AVERAGE WINTER EGG PRODUCTION FOR EACH MONTH OF 1915–16, GROUPED BY MONTH HATCHED

Month Hatched, 1915	Number Pullets	Average Winter Production	August	September	October	November	December	January	February
February.....	51	56.2	2.7	8.3	8.3	7.1	6.8	10.1	12.9
March........	122	39.8	0.0	0.4	2.3	6.2	10.4	10.0	10.3
April.........	173	29.8	0.0	0.0	0.02	1.1	6.1	10.5	12.0
May.........	136	18.1	0.0	0.0	0.0	0.0	0.8	5.4	11.9

least not at present, so that the coefficient was calculated for one of the largest hatches only. The value found, $r = -.829 \pm .029$, is in full agreement with the hypothesis that the winter egg production of a flock all hatched at the same time, depends largely upon the age at which the first egg is produced.

TABLE IV

AVERAGE WINTER EGG PRODUCTION FOR EACH WINTER MONTH OF 1913–14, BY HATCHES

Date Hatched, 1913	Number Pullets in Hatch	Average Winter Production	August	September	October	November	December	January	February
March 9	10	53.3	......	......	......	3.7	12.7	18.6	18.3
March 16	12	44.8	......	......	......	1.6	11.3	16.8	15.1
March 23	22	47.1	......	......	......	0.3	10.3	19.4	17.1
March 30	17	36.5	......	......	......	0.0	7.7	13.9	14.9
April 6	29	48.6	......	......	......	2.4	11.4	18.0	16.9
April 13	19	41.2	......	......	......	1.2	8.4	16.1	15.6
April 20	37	35.2	......	......	......	0.2	3.3	15.9	15.8
April 27	40	32.5	......	......	......	0.1	4.1	12.5	15.9
May 4	9	42.2	......	......	......	0.0	4.0	19.6	18.7
May 11	13	25.2	......	......	......	0.0	1.3	8.6	15.3

TABLE V

AVERAGE WINTER EGG PRODUCTION FOR EACH MONTH OF 1915–16, OF STOCK FROM ORIGINAL SOURCE

Date Hatched, 1915	Number Pullets in Hatch	Average Winter Production	August	September	October	November	December	January	February
March 22	35	41.11	0.0	0.0	2.3	4.2	7.9	12.8	13.9
April 27	16	23.31	0.0	0.0	0.0	0.0	2.6	8.4	12.3

TABLE VI

A COMPARISON OF THE PROPORTION OF THE FLOCK LAYING EITHER MORE OR LESS THAN 30 EGGS DURING THE WINTER, TOGETHER WITH THE MEANS OF THE RESPECTIVE GROUPS, GROUPED ACCORDING TO THE MONTH HATCHED. THE ZERO PRODUCERS HAVE BEEN OMITTED AND ALSO THE FEW BIRDS THAT LAID EXACTLY 30 EGGS

Month	Over 30			Under 30		
	Av. Winter Production	Number Individuals	Per Cent.	Per Cent.	Av. Winter Production	Number Individuals
February	63.0	43	84.3	15.7	18.8	8
March	54.9	77	68.8	31.3	16.4	35
April	46.3	88	58.7	41.3	16.0	62
May	40.5	29	26.6	73.4	16.1	80

The influence of the time of hatching on winter egg production is shown in Fig. 8 and Table II and III based on the records for 1915–16. The lower graph in Fig. 8 is for birds hatched in March; the middle graph for birds hatched in April; while the upper is for the May-hatched birds. Similar data for 1913–14 are given in Table IV.,

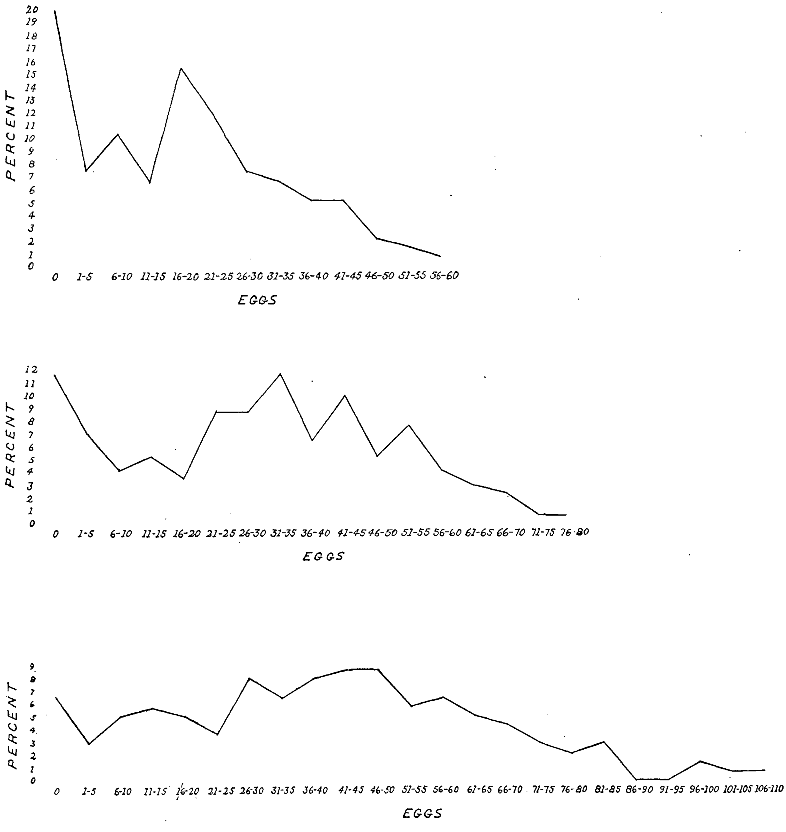

FIG. 8. The effect of time of hatching on winter egg production, the graph showing the per cent. of flock laying the specified number of eggs for the winter period of 1915–16. Lower curve, pullets hatched in March, 1915. Middle curve, pullets hatched in April. Upper curve, pullets hatched in May. M. for March = 42.65, April = 35.4, May = 22.5; S. D. for March = 23.50, April = 17.91, May = 15.58; C. V. for March = 5.5, April = 55, May = 69.2.

It has seemed to the writer that for Rhode Island Reds, the zeros formed a wholly artificial class for reasons given in the text; hence, March 1 marks no natural division point in the time at which the birds begin to lay. Consequently, the zero class has been kept separate and not included in calculating these constants. If M includes the zero class, its value for March is 39.8, for April 29.81 and for May 18.1.

while Table V. should also be examined in this connection. It is clear from these graphs that the earlier hatched birds are superior to the later hatched for winter egg production. In the former group there are fewer zero and more very high producers than in the last. There is also a marked difference in the number of birds in each of the several hatching months that laid over thirty eggs during the winter period. (See Table VI.)

The variability in the age at which the first egg is produced influences the winter record strongly, so much so that we have been led to believe that it is the most important determining factor for egg production during the winter months for our flocks.[3] It leads to the abandonment of the view that those records that fall below 30 eggs are made by true mediocre producers, substituting therefor the view that many, perhaps most, of them are late-maturing high producers. Now, the variability in age at first egg, shown in Figs. 1 and 2, is considerable. If this variability could be eliminated—that is, if it were possible to have each individual of a flock of birds hatched April 1, begin to lay on a definite date, say December 1—the birds would make records which would differ from each other in the proportions given by the graphs of rates of production. The fair degree of homogeneity of the flocks in respect to rate of production is shown in part by the coefficient of correlation between the number of days from the first egg laid up to March 1, and the number of eggs produced during that period. The coefficient was found to have a high value, *i. e.*, for 1913–14, $r = +.8618 \pm .0125$ and for 1915–16, $r = +.7878 \pm .0128$. That is, the number of eggs laid is a fairly definite function of the length of the laying period. These coefficients are a rough index of the amount of homogeneity in the flock respecting the rate of production, since a high coefficient implies a fair amount of homogeneity in the flock (*cf.*, however, the statistical constants for rate) for if an egg a day is taken to represent the maximum production while

[3] The results obtained from our breeding tests substantiate this point.

the minimum is represented by a single egg laid during the winter and that one at the beginning of the winter period, no correlation would exist if the scatter is perfect between these extremes. Experience shows, however, that conditions approached by the maximum rate of production are much more common than those represented by the minimum so that the coefficient, even though it has a high value, shows only that the rate of production is comparatively uniform. It does not prove that the flock is composed exclusively of high producers, for, since it is an average figure, the flock may still contain some true mediocre producers. A certain degree of correlation, however, is to be expected in any flock, so that the mere existence of a small positive correlation is of little value, though a low value for the coefficient would imply that there was considerable variability in rate of production. It is quite clear that if a considerable percentage of the flock made records like those shown in Fig. 12, the variability in rate would be much greater than observed, and the coefficient of correlation between length of laying period and number of eggs would be smaller.

Size.—Size does not of itself seem to have any specific relation to a bird's ability to lay because birds of all sizes may lay equally well once they have started. It is true, of course, that very large birds rarely make high records, but as there are very few large birds, the chance for a combination between very high egg production, itself uncommon, and large size is rather remote. The converse, however, is not apparently true, for small birds frequently make good records. Since, however, birds that are too small are not desired by poultrymen while as a rule large birds are considered desirable, very small birds are not often trap-nested, so that a strict comparison is at present impossible.

In another way size seems to exert some influence on the record a hen makes. On the average, as shown by the coefficient of correlation between age at first egg and weight, birds of large size reach this size later in life

than small birds do. That is, large size usually, but not always, results from long-continued growth rather than from very rapid growth and as long-continued growth naturally tends to postpone the date at which the first egg is laid, the large hen, other things being equal, can not lay as many eggs. It is possible, however, that the case may actually be the converse, viz., the hen may grow large because she does not lay, though there is no definite evidence for this point of view. While it is easy to find many instances of small birds that mature late in life, instances of large birds maturing at the same age as birds of approximately half their body weight have not been observed. The reason for this is probably to be found in the consideration that while some large birds may grow more rapidly than some small birds, it is always possible for some small birds to grow as fast as it is ever possible for a large bird to grow and hence to mature that much earlier.

(*To be continued*)